



# Prehistoric occupation and palaeoenvironmental changes along Santa Catarina's Coastal Plain, Brazil: An integrated approach based on palynological data

Cristina Val-Peón<sup>a,b,\*</sup>, Rodrigo R. Cancelli<sup>c</sup>, Luís Santos<sup>d,e</sup>, André L.R. Soares<sup>f</sup>

<sup>a</sup> Institut Català de Paleocologia Humana i Evolució Social (IPHES), Zona Educacional 4, Campus Sescelades URV (Edifici W3), 43007 Tarragona, Spain

<sup>b</sup> Àrea de Prehistòria, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, 43002 Tarragona, Spain

<sup>c</sup> Instituto de Geociências, Centro de Estudos de Geologia Costeira e Oceânica - CECO, Universidade Federal de Rio Grande do Sul, Campus do Vale Av. Bento Gonçalves, 9500 Porto Alegre, RS, Brazil

<sup>d</sup> Departamento de Arqueologia, Instituto Politécnico de Tomar, Estrada da Serra, 2300-313 Tomar, Portugal

<sup>e</sup> Centro de Geociências, Faculdade de Ciências e Tecnologia da Universidade de Coimbra, Largo Marquês de Pombal, 3000-272 Coimbra, Portugal

<sup>f</sup> Departamento de História, Universidade Federal de Santa Maria, Av. Roraima n° 1000, Cidade Universitária Bairro Camobi Santa Maria, 97105-900, RS, Brazil

## ARTICLE INFO

### Keywords:

Archaeology  
Palaeopalynology  
Holocene  
Palaeoenvironmental evolution  
Prehistoric settlements

## ABSTRACT

Climate change and sea level variation during the Quaternary shaped the southernmost Santa Catarina's Coastal Plain and its landscape, promoting vegetation changes and different geomorphological features that resulted in the formation of sand barriers, relocation of fluvial channels, lagoons and rivers. In this context, prehistoric occupation of the territory took place through different migratory events over the Holocene. This study presents a palaeoenvironmental reconstruction of the last 8000 years BP, based on pollen analysis from the core collected in Campo Mãe Luzia natural deposit (Araranguá municipality, SC, Brazil). The palynological, sedimentary, chronological and altimetric records were integrated with a revision of the archaeological data, allowing for the contextualization of the different groups within each environmental phase. Three distinct palaeoenvironmental phases are suggested for the last 8000 years BP: Phase I, characterized as an estuarine-lagoon environment, with no reports of human occupation; Phase II, a transition between the lagoon environment and the gradual formation of a coastal swamp, followed by an expansion of the sandy coastal barrier; Phase III, characterized by Atlantic rain forest development and their colonization. Human occupation was registered in the last two phases, with settlements of hunter-gatherer groups, *sambaquis* builders, and Meridional Jê and Guaraní groups.

## 1. Introduction

According to Barboza et al. (2014), Dillenburger et al. (2009, 2014) and Silva (2015), palaeoenvironmental changes during the Quaternary modified Santa Catarina's southern Coastal Plain morphology. Several broad-scale factors, such as climate change, were important in the landscape configuration; however, a multiplicity of agents with local and regional actuation, especially those related to coastal dynamics, seem to have been equally decisive in environmental variations during the Holocene (Hesp et al., 2009).

In this scenario, diverse prehistoric groups occupied the territory and a different set of relationships was established between them and their environment: survival strategies, exploitation, and management of resources. To further understand the relationships between prehistoric humans and palaeoenvironment, our study employs palynology as a source of data comparable to the archaeological record.

Palynological studies of natural deposits in the Coastal Plain are concentrated in the northern region of Volta Velha (Behling, 1995; Behling and Negrelle, 2001) and the southern extreme in the Sombrio (Cancelli, 2012; Cancelli et al., 2012a, 2012b). On the other hand, archaeological research in the region, though is relatively recent, resulted in a number of surveyed sites and a few excavations with chronological control (Campos et al., 2013; Campos, 2015; Lavina, 2000; Lino, 2009).

A sediment core was collected in a peat bog in the Campo Mãe Luzia locality for analysis and identification of palynomorphs contained in the sediment. This core will also enable the interpretation of the landscape evolution, thus integrating both palynological and archaeological data, in order to understand the environmental evolutionary sequence during the prehistoric settlement and resource exploitation.

\* Corresponding author.

E-mail address: [cvpwol@gmail.com](mailto:cvpwol@gmail.com) (C. Val-Peón).

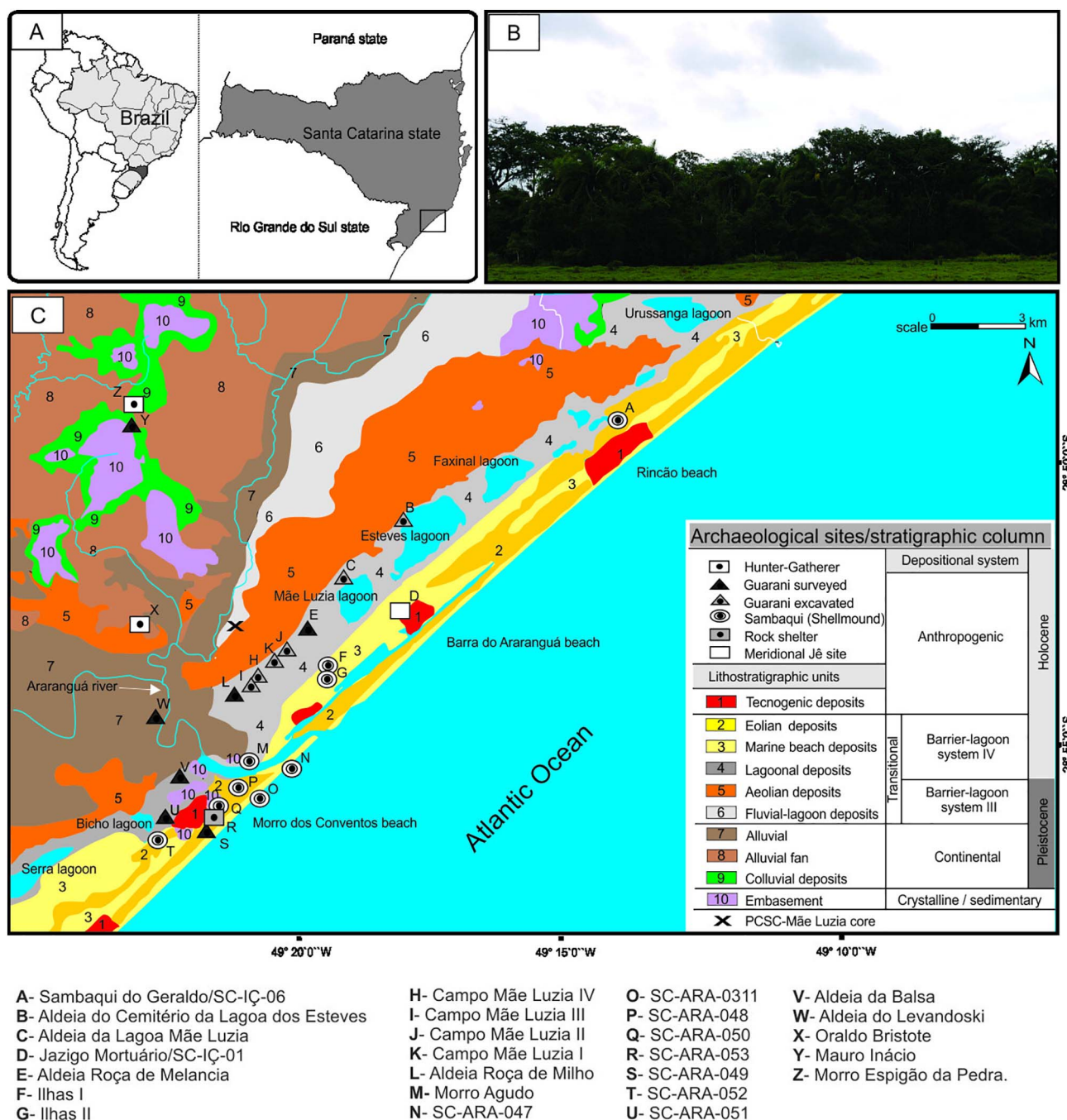


Fig. 1. A. study area; B. local vegetation characteristics where the core was drilled; C. geological map adapted from Horn et al. (2012), showing the Campo Mãe Luzia peat bog (X), the stratigraphic column and archaeological sites.

## 2. Regional setting

### 2.1. Depositional systems, climate, and vegetation

The meridional Coastal Plain of the Santa Catarina state is situated in the continental portion of Pelotas Basin, which is composed of continental and coastal deposits. The continental system is associated with the plateau slopes (colluvial, alluvial-fan and fluvial deposits). Coastal deposits related to sea level fluctuations, formed a four barrier-lagoon system during the Quaternary (Giannini et al., 2007; Horn Filho et al., 2012; Villwock et al., 1986; Villwock and Tomazelli, 1995) (Fig. 1C). The studied peat bog is located in an area where the barrier-lagoon system III, formed by lagoonal and aeolian deposits during the Pleistocene, is superimposed by barrier-lagoon system IV, formed by

lagoonal, marine/beach and aeolian sediments during the last Holocene transgression ca. 5100 BP (Horn Filho et al., 2012). The main river in the area is the Araranguá, a meandering river in whose mouth, the current Holocene regressive barrier has shown a standard progradation since the last 8–7 ka, observing land reclamation sea through the deposition of sediments (Dillenburger and Barboza, 2014). Initially, the river channel mouth was parallel to the sea, moving towards NE due to the longshore drift in the same direction. However, in recent years, the river channel is shifting as a result of shoreface/beach deposits erosion (Silva et al., 2010, 2014; Silva, 2015).

According to Köppen (1948) climate classification, the region is classified as humid subtropical mesothermal climate, with an annual average temperature of around 19 °C, a high relative humidity of ~82% and without dry season. This area is affected by the Atlantic Polar

Front, which is in turn responsible by the orographic precipitations in the littoral, which are propitiated by the Serra Geral, and the South Atlantic Convergence Zone (SACZ). A constant NW-SE belt of condensation with special activity in summer determines the distribution of the precipitations in the region (Diehl and Horn Filho, 1996; Nimer, 1989).

The region part of the Atlantic Forest Biome, more specifically the phytocological region characterized as the Lowland Atlantic Rain Forest, which in the Coastal Plain fringes with the salt marsh vegetation or *restinga* (IBGE, 2012).

## 2.2. Archaeological context

In the Santa Catarina state, it is possible to distinguish diverse prehistoric groups defined by specific characteristics in settlement patterns and material culture, as well as different strategies in environmental adaptation. The hunter-gatherer groups were located in the mountains slopes and the upper Uruguay River forests between 10,000–1000 BP, which does not exclude sporadic coastal incursions. In the Coastal Plain, the oldest occupations correspond to *sambaquis* builders' (Brazilian shellmounds), established along the littoral ca. 8000–2000 BP. The migratory wave of ceramist groups implies two archaeological traditions under which is possible to differentiate two human groups that have occupied the territory in two different moments: the oldest, the Meridional Jê groups, associated with the Taquara-Itararé tradition, occupied the Coastal Plain and the Serra Geral ca. 1500 BP; the latest, the Guaraní groups, associated with the Tupiguarani tradition, occupied the Coastal Plain and the Serra Geral in the last 700 years BP (Campos et al., 2013; Campos, 2015; DeBlasis et al., 2007; Dias, 2004; Noelli, 1999; Prous, 1991; Schmitz, 2013) (Fig. 1C).

Although with some regional differences, prehistoric settlements in the meridional Coastal Plain plausibly coincide with these patterns for the whole state. Based on recent research, it is possible to acknowledge the following dynamics: a weak presence of hunter-gatherers, with some reference chronologies in the nearest excavations of  $3000 \pm 120$  BP,  $910 \pm 200$  BP and  $290 \pm 80$  BP in Alfredo Wagner, Urubici and Presidente Getúlio municipalities, respectively (Farias, 2005; Noelli, 2000); eight surveyed sites characterized as *sambaquis*, with one excavation and a chronology of  $3340 \pm 70$  BP in Balneário Rincão municipality (Rogge and Arnt, 2006); a funerary Meridional Jê site, excavated and with a chronology of  $1580 \pm 50$  BP in Balneário Rincão municipality (Schmitz, 1995, 1999); seven surveyed and six excavated Guaraní sites (Araranguá and Balneário Rincão municipalities), which show an occupation during the last 700 BP (Campos et al., 2013; Campos, 2015; Lavina, 2000; Lino, 2009).

## 3. Material and methods

The Campo Mãe Luzia core was collected in a peat bog located in the Araranguá municipality ( $28^{\circ}52'53.42''S$ ,  $49^{\circ}21'33.05''W$ ). A Russian peat borer was used for drilling, reaching a maximum depth of 7 m. The core was collected in sections of 50 cm, which were photographed, wrapped in plastic and aluminium paper, and transported to the laboratory, where they were stored at  $4^{\circ}C$ . A total of 16 samples ( $2\text{ cm}^3$  each) were taken at 25 cm intervals along the first 300 cm and at 95 cm intervals along the last 4 m. A *Lycopodium clavatum* spore tablet ( $18.584 \pm 371$  BP) was added to each sample as a quantitative marker in order to calculate pollen concentrations (Stockmarr, 1971). The selection criteria were based on taking samples that could be representative of each one of the sediment types. The particular interest in the 3 most superficial meters is justified by the major recent lithological changes, which results are important towards the understanding of the palaeoenvironmental evolution and the connection with archaeological data. The samples were processed according to Faegri and Iversen (1989), using HF, HCl, KOH and acetolysis, with a final sieving

to concentrate  $< 180\text{ }\mu\text{m}$  fractions. Pollen grains, spores and other palynomorphs were identified on the slides under  $400\times$  magnification; a minimum of 300 pollen grains were counted in each slide, except for the samples with a low pollen concentration, in which a minimum of 150 spores of exotic marker were counted, respecting the Lorscheitter and Roth (2013) methodology. Identification was possible through reference material of the palynomorphs of the SE Brazilian flora (Bauermann, 2003; Cancelli, 2012; Cancelli et al., 2012a; Cancelli et al., 2012b; Colinvaux et al., 1999; Leal and Lorscheitter, 2006; Leonhardt and Lorscheitter, 2007; Lorscheitter, 1988, 1989; Macedo et al., 2009; Medeanic, 2006; Medeanic et al., 2007, 2010; Neves and Lorscheitter, 1992, 1995). When a very low percentage of taxonomically undetermined pollen and spores were counted, they were excluded from the diagram.

Pollen and spores were calculated as percentages of the pollen sum using Tilia and TiliaGraph Program (Grimm, 1987), including all the identified taxa of trees and shrubs, herbs, epiphytes, aquatic plants, ferns, and mosses. Considering the main objective of our work is reconstructing the palaeoenvironmental evolution from a local and regional point of view, especially in relation to the palaeolagoon formation, the total sum includes all the identified palynomorphs, which were classified in continental (herbs, trees, shrubs, epiphytes, ferns, mosses and fungi) and aquatic-marine elements (aquatics, algae, dinoflagellates and palynoforaminifera). The continental and aquatic-marine percentages, previously transformed per square-root, were used to perform the cluster analysis (stratigraphically constrained), using CONISS of Tilia, TiliaGraph (Grimm, 1987), in order to understand the relations between the different factors and serve as base for the subdivisions of palaeoenvironmental phases.

Altimetric data was acquired through a Trimble R6-2012 GPS device and a Topcon 3200 Total Station. The Trimble Business Center (TBC) software was used to process the point tracked by the GPS and correct the elevation with the software IBGE-MAPGEO2010, obtaining a reference quota of the site at 1102 m above current sea level.

Six sediment samples were dated by accelerator mass spectrometry (AMS) which were calibrated at the Beta Analytic Radiocarbon Dating Laboratory (Florida, USA), using the Pretoria Calibration Procedure program and the SHCAL13 calibration database (Hogg et al., 2013; Talma and Vogel, 1993) (Table 1).

## 4. Results

### 4.1. Altimetry, sedimentological description and radiocarbon dates

The altimetric data acquired by precision equipment, accused 1,102 m above sea-level for the top of this core. The Mãe Luzia core is a 0–700 cm section of unconsolidated sediments, showing three stratigraphic sedimentary intervals from the base to the top. The sediment core is composed of gray silty clay material from 700 to 130 cm, with micro-molluscs identified as the gastropod *Heleobia australis* concentrated between 300 and 180 cm. From 130 to 65 cm, is composed of

**Table 1**

Radiocarbon dates from the Campo Mãe Luzia core. All the samples collected for dating were composed of organic sediment. PMC indicates the percent of modern carbon and the asterisk (\*) specifies that no calibrated age was calculated.

Lab. number	Depth (cm)	Conventional Age ( $^{14}C$ yr B.P)	Age range (cal. BP 2 $\sigma$ , 95% probability)	Media (cal. yr BP)
Beta-412090	0 cm	102.8 $\pm$ 0.3 pMC	*	*
Beta-412091	50 cm	2230 $\pm$ 30 BP	2310–2100	2205 $\pm$ 105
Beta-412092	100 cm	2720 $\pm$ 30 BP	2845–2750	2797 $\pm$ 48
Beta-412093	200 cm	5480 $\pm$ 30 BP	6295–6195	6245 $\pm$ 50
Beta-412094	400 cm	6510 $\pm$ 30 BP	7430–7320	7375 $\pm$ 55
Beta-412095	700 cm	7240 $\pm$ 30 BP	8030–7960	7995 $\pm$ 35



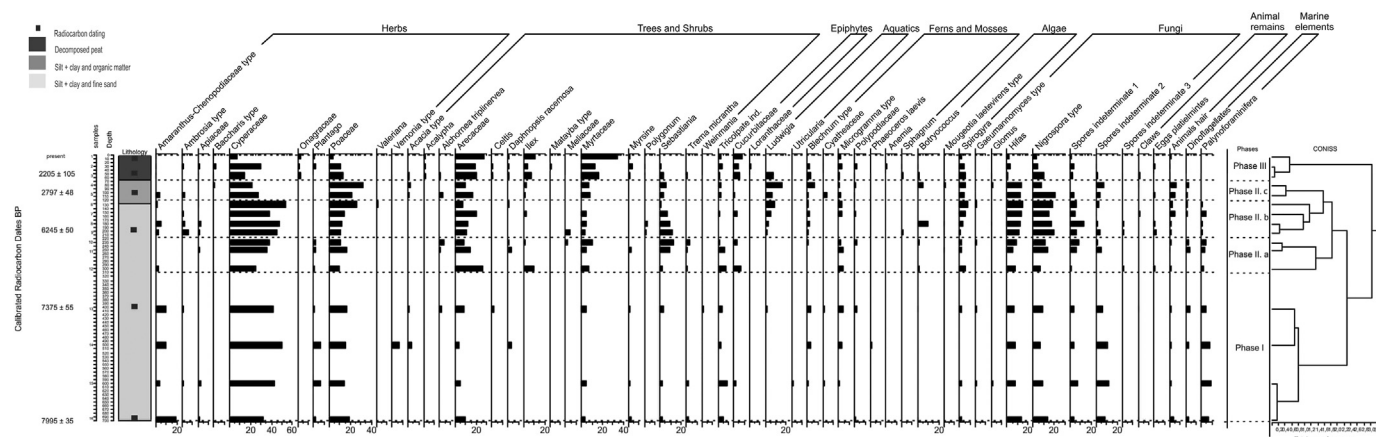


Fig. 2. Pollen percentage diagram of the most important and frequent taxa grouped into herbs, trees and shrubs, epiphytes, aquatics, ferns and mosses, algae, fungi, animal remains and marine elements. The stratigraphy, the AMS radiocarbon dates and the cluster analysis are also indicated.

brown-gray silty clay with accumulated organic matter. On top, between 65 cm and the surface, the deposit is formed by brown decomposed peat (Fig. 2).

Six AMS radiocarbon dates provide chronological control for the Campo Mãe Luzia pollen record, indicating Holocene deposits with the oldest record dating  $7995 \pm 35$  BP (Table 1).

#### 4.2. Description of the diagram

A total of 43 types of palynomorphs were identified in 16 samples analysed from the core (Table 2). According to major changes in palynomorph assemblages and the cluster analysis, three phases were defined (Figs. 2 and 3). Undetermined palynomorphs exist in a low percentage, reason why they were not included in the diagrams and cluster analysis.

Phase I extends from sample 16 to sample 13, corresponding with the age range from  $7995 \pm 35$  BP to a point between

$7375 \pm 55$ – $6245 \pm 50$  BP. It is characterized by a predominance of herbal taxa, especially *Cyperaceae* (32–50%), *Poaceae* (15–20%) and *Amaranthus-Chenopodiaceae* (5–20%). Arboreal pollen frequencies are low and mostly from *Arecaceae* (3–10%) and *Myrtaceae* (5%). Fungal spores are represented by *Nigrospora* type (6–19%). Spores of *Microgramma* (1–5%) and *Blechnum* type (1–4%) occur in low percentages, as well as *Spirogyra* spores (3%). Dinoflagellate cysts (5%) and palynoforaminifera linings (5–11%) were found throughout this phase.

Phase II extends from sample 12 to sample 4. It begins between  $7375 \pm 55$ – $6245 \pm 50$  BP and it ends in the age range from  $2797 \pm 48$  BP to  $2205 \pm 105$  BP, which is characterized by a dominance of herbal taxa and a progressive increase of arboreal pollen. However, some tendencies, which permit a division into three sub-phases, are observed. Phase II.a (from sample 12 to sample 10) shows a predominance of *Cyperaceae* (35–40%) and *Poaceae* (10–20%) with an increase of *Arecaceae* (10–25%), *Ilex* (2–10%) and *Myrtaceae* (5–15%). *Sebastiania* (5–15%) and *Alchornea* (1–5%) were identified, as well as epiphytes, as *Cucurbitaceae* (3–6%). *Microgramma* type (2–7%) was found. Algae spores are mainly represented by *Spirogyra* (2–8%) and fungal spores by *Nigrospora* type (9–15%). Dinoflagellate cysts (4–6%) and palynoforaminifera linings (4–6%) were also identified. Phase II.b (from sample 9 to sample 6) is quite similar to the previous sub-phase: it exhibits a predominance and a slight increase of *Cyperaceae* (35–50%) and *Poaceae* (15–30%) with the presence, and a slight decrease, of *Arecaceae* (10–29%) and *Myrtaceae* (5–8%). *Sebastiania* (2–12%) was also identified, as well as *Cucurbitaceae* (3%). The main difference compared with the previous sub-phase is the occurrence of the aquatic taxa *Ludwigia* (2–10%), *Blechnum* (2–4%) and *Microgramma* type (5%) were also present. An increase of *Spirogyra* (2–10%) and fungal spores of *Nigrospora* type (15–20%), as well as animal hairs (2–7%), were identified. Dinoflagellate cysts (2%) and palynoforaminifera linings (2–6%) still present. During the Phase II.c (samples 5 and 4) herbaceous pollen is predominant, mostly from *Cyperaceae* (15–50%) and *Poaceae* (20–30%). A slight increase in the concentration of tree pollen is observed, as well as in the diversity of: *Myrtaceae* (5–10%), *Arecaceae* (9–15%), *Alchornea* (4%), *Sebastiania* (1–8%), *Ilex* (3%) and *Acacia* type (1–4%). The aquatic taxa represented by *Ludwigia* rise progressively (10–15%) towards the end of the sub-phase. Fern spores increase, including tree fern *Cyathea* type. Similar percentages to the previous sub-phase of algae and fungal spores, as well as animal hairs, were observed. Dinoflagellate cysts (3–5%) were identified, but palynoforaminifera linings disappears from sample 5 (105 cm) exhibiting the trend until top of the core.

Phase III extends from sample 3 to sample 1, corresponding with the age range from  $2797 \pm 48$  BP to  $2205 \pm 105$  BP until the present. This phase is marked by the decrease of herbal taxa, *Cyperaceae* (9–28%) and *Poaceae* (3–15%), and the increase of shrubs and tree pollen, especially *Arecaceae* (20–25%) and *Myrtaceae* (15–35%). Different taxa were identified in low percentages, as *Celtis*, *Ilex*, *Myrsine*,

Table 2  
Classification of the palynomorphs identified in the samples.

Sporopollinic material	
Herbs	<b>Amaranthus-Chenopodiaceae</b> ; <b>Apiaceae</b> : <i>Eryngium</i> ; <b>Asteraceae</b> : <i>Ambrosia</i> type, <i>Baccharis</i> type, <i>Vernonia</i> type; <b>Cyperaceae</b> ; <b>Onagraceae</b> ; <b>Plantaginaceae</b> : <i>Plantago</i> type; <b>Poaceae</b> ; <b>Valerianaceae</b> : <i>Valeriana</i> type.
Trees and shrubs	<b>Arecaceae</b> ; <b>Aquifoliaceae</b> : <i>Ilex</i> ; <b>Cannabaceae</b> : <i>Celtis</i> , <i>Trema micrantha</i> ; <b>Euphorbiaceae</b> : <i>Acalypha</i> , <i>Alchornea</i> , <i>Sebastiania</i> ; <b>Fabaceae</b> : <i>Acacia</i> type; <b>Meliaceae</b> ; <b>Myrsinaceae</b> : <i>Myrsine</i> ; <b>Myrtaceae</b> ; <b>Polygonaceae</b> : <i>Polygonum</i> ; <b>Sapindaceae</b> : <i>Matayba</i> ; <b>Thymelaceae</b> : <i>Daphnopsis racemosa</i> .
Epiphytes	<b>Cucurbitaceae</b> ; <b>Loranthaceae</b> .
Aquatics	<b>Lentibulariaceae</b> : <i>Utricularia</i> ; <b>Onagraceae</b> : <i>Ludwigia</i> .
Exotics	<b>Betulaceae</b> : <i>Alnus</i> .
Pteridophytes	<b>Anemiaceae</b> : <i>Anemia</i> ; <b>Blechnaceae</b> : <i>Blechnum</i> type, <i>Cyathea</i> type; <b>Polypodiaceae</b> : <i>Microgramma</i> type, <i>Polypodium</i> .
Bryophytes	<b>Anthocerotaceae</b> : <i>Phaeoceros</i> , <i>Sphagnum</i> .
Other palynomorphs	
Algae	<b>Dyctyosphaericeae</b> : <i>Botryococcus</i> ; <b>Zygnemataceae</b> : <i>Mougeotia</i> , <i>Spirogyra</i> .
Fungi	<b>Dematiaceae</b> : <i>Nigrospora</i> type; <b>Glomeraceae</b> : <i>Glomus</i> ; <b>Magnaporthaceae</b> : <i>Gaeumannomyces</i> type.
Dinoflagellates	One undetermined typology.
Palynoforaminifera	Two undetermined typologies.
Animal remains	Claws, <i>Platelmintes</i> eggs, jaws and hairs.

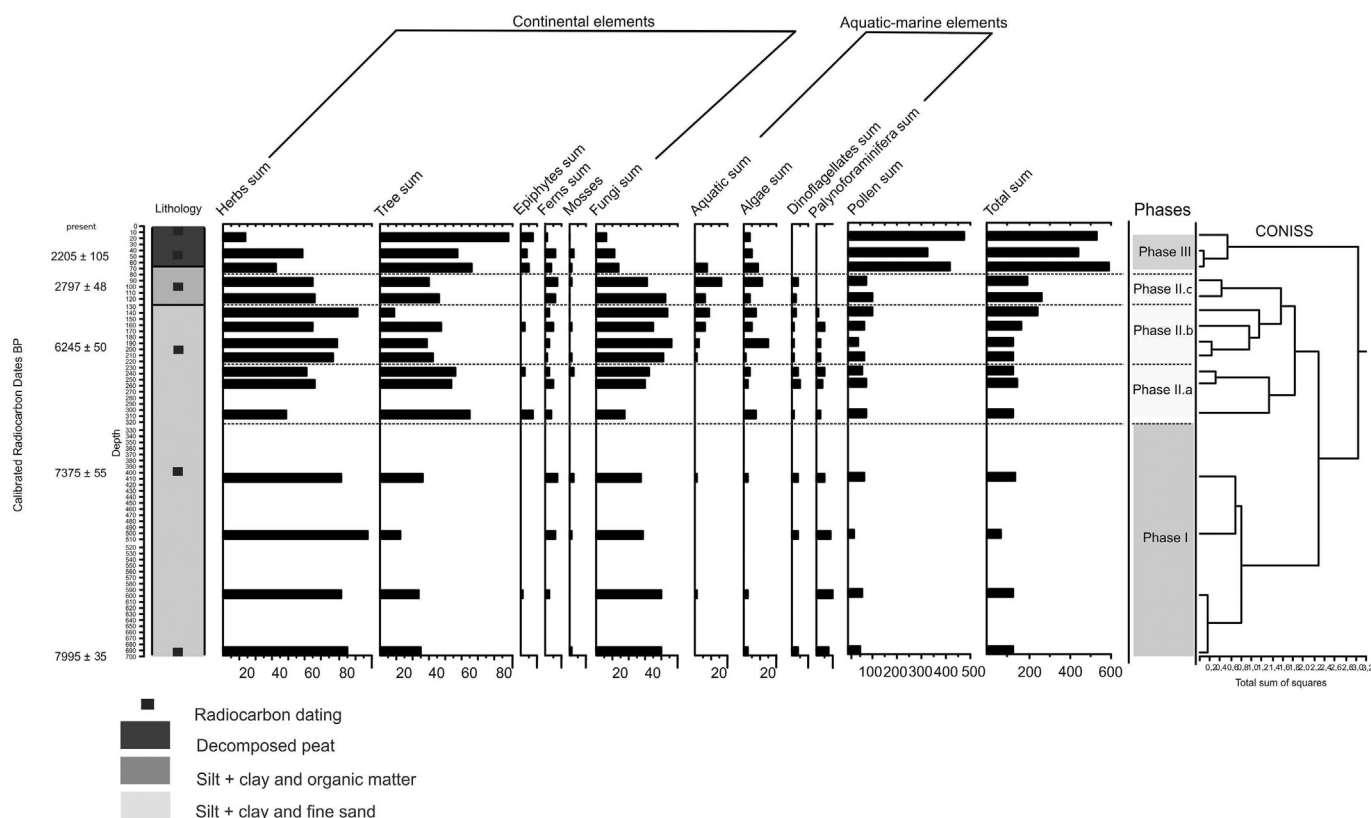


Fig. 3. Pollen summary diagram grouped into continental and aquatic/marine elements. The stratigraphy, the AMS radiocarbon dates and the cluster analysis are also indicated.

*Acalypha*, *Sebastiania* and *Daphnopsis racemosa*. Epiphytes represented by *Cucurbitaceae* (5–10%) reach a maximum and the aquatic taxa *Ludwigia* disappears progressively. Ferns, algae and fungal spores decrease gradually towards the top of the core. Dinoflagellate cysts disappear from sample 3 (55 cm) up to the top of the core.

## 5. Discussion

### 5.1. Palaeoenvironmental evolution

#### 5.1.1. Estuarine-lagoon (Phase I)

The vegetation, mostly herbaceous, is composed by taxa characteristic of marshes, swamps, interdune depressions and water bodies' shores of the region (Cordazzo and Seeliger, 1995; Medeanic, 2006). The identified arboreal taxa are common in the *restinga* formations and they are also distinctive in the development stages of the Atlantic rain forest (IBGE, 2012). Algae, although scarce, are represented by freshwater taxa which can adapt to a certain degree of salinity (Medeanic et al., 2007; Medeanic and Côrrea, 2010). The presence of dinoflagellate cysts and palynoforaminifera linings, both identified from the base of the core, indicate marine influence. Palynoforaminifera linings and dinoflagellate cysts peaks are common in other palaeolagoon deposits from the Santa Catarina's Coastal Plain (Amaral et al., 2012; Cancelli, 2012) and from the northern Coastal Plain of Rio Grande do Sul (Bauermann, 2003; Lorscheitter and Dillenburg, 1998; Macedo et al., 2007; Meyer et al., 2005). The pollen analysis of some surface sediments collected in the Sombrio area (Cancelli, 2012) have shown that some representative taxa of this Phase I also occurs in contemporaneous lagoonal contexts, where the vegetation is mainly formed by herbaceous pollen (*Amaranthus-Chenopodiaceae*, *Asteraceae*, *Cyperaceae* and *Poaceae*) accompanied by low arboreal frequencies (*Arecaceae*, *Myrtaceae*).

Between 7995 ± 35 BP and 7375 ± 55 BP, 3 m of sediment were deposited and the causes of this high rate of sedimentation is unknown,

though sand scarcity seems to indicate the sediment was not oceanic origin, contrarily, it derived from erosional deposition from the nearby mountain slopes. As a result, considering the base of the core in 7 m, and taking into account the altimetry of 1106 m above sea level, the palaeolagoon would have passed from 6 m to 2 m below the current sea level in approximately 1000 years (Fig. 4A).

It is possible to consider a scenario in which the Araranguá River would have served as an ocean entrance channel, resulting in lowland flooding. However, the progressive development of the Holocene sandy barrier would have acted as a limit, otherwise (or in earlier times) an estuarine river mouth could have existed (Silva et al., 2014). A joint action of these factors would have led to the formation of the large palaeolagoon in low lands, where the barrier-lagoon system IV deposits were sedimented, in part, over the barrier-lagoon system III deposits (Horn Filho et al., 2012). This interpretation of a palaeolagoon environment is confirmed by the palynological results, sedimentary texture and the constant presence of *Heleobia australis* throughout the 695 cm to 300 cm.

#### 5.1.2. Transitional lagoon/swamp (Phases II.a and II.b)

The herbaceous vegetation is similar to the previous phase, with a progressive increase of *Ludwigia* (Phase II.b), an aquatic genus common in lacustrine, fluvial and palustrine systems (Cordazzo and Seeliger, 1995; Reitz, 1961). The slight diversification of tree taxa, although with a low pollen concentration, indicates a slow and progressive colonization of the regional flora in the surrounding areas of the water body and the highlands. There is a modest increase of fungal spores, typical from forest and sandy soils, and from transitional environments, such as mangroves and swamps (Domsch et al., 1980). Some animal remains appear, mostly hairs, which could indicate a more favourable environment for some animals to shelter.

A palynoforaminifera lining peak before the end of the Phase II.b occurs associated with a decrease of arboreal cover and a consequent increase of herbal covers. This data could indicate a moment of

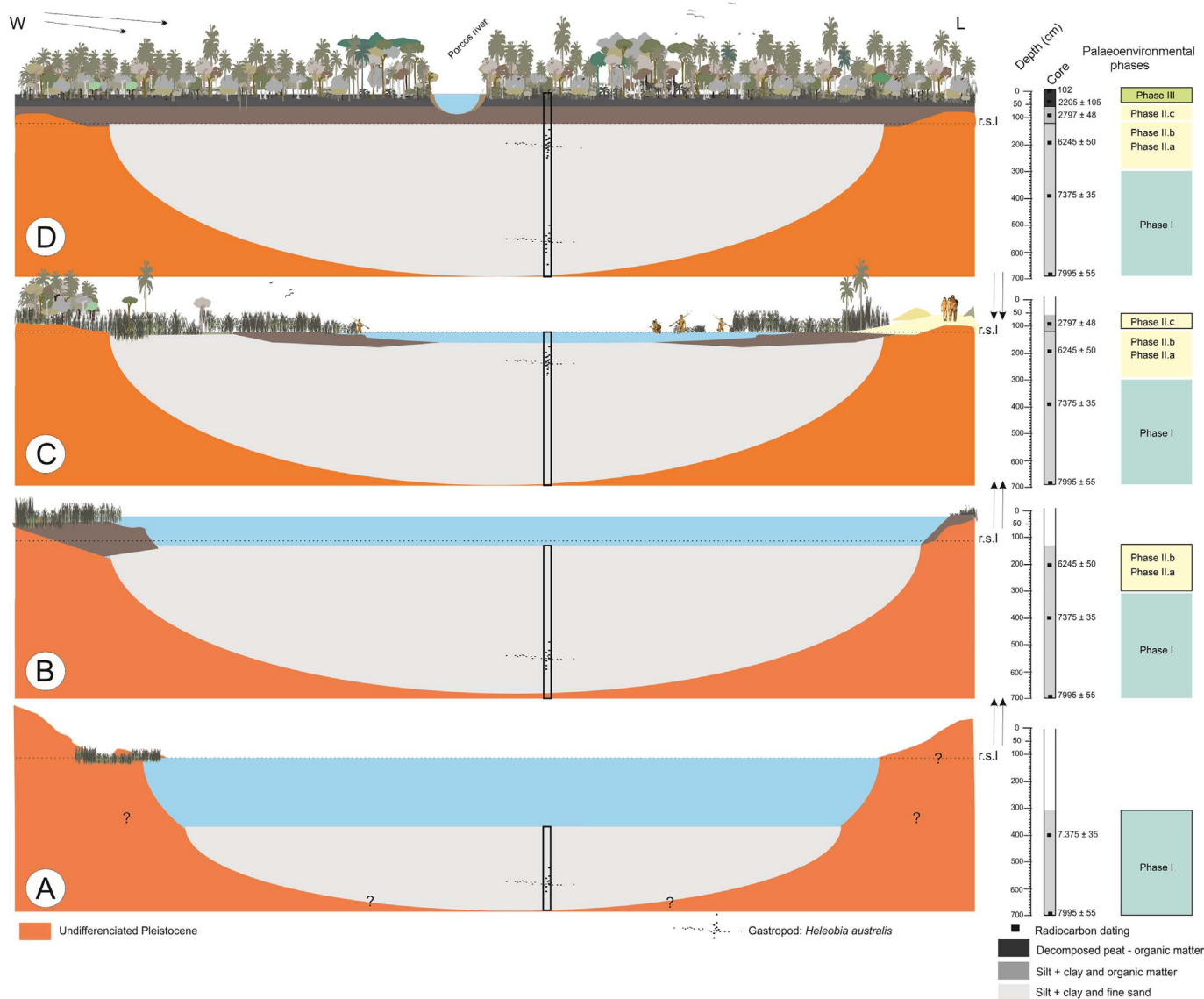


Fig. 4. Palaeoenvironmental reconstruction of the region in the last 8 ka years BP: A-Phase I, estuarine-lagoonal; B- Sub-phase II.a and II.b, transition between lagoon-coastal swamp; C- Sub-phase II.c, transitional coastal swamp; D- Phase III, forest consolidation.

maximum marine influence, documented ca. 5100 BP in the region, which is coherent with the palynological and chronological data obtained in Jaguaruna and Sombrio municipalities (Amaral et al., 2012; Cancelli, 2012).

Considering the calibrated ages between the middle/end of the previous phase and the middle/end of this phase, a sedimentation decrease is observed, with a 2 m deposition between  $7375 \pm 55$  BP and  $6245 \pm 50$  BP, which implies a reduction of almost half in relation to the previous phase, and a continuity in the loss of the lagoon's depth (Fig. 4B).

The mix of diverse elements in this phase does not allow the establishment of clear boundaries, however, it is possible to take into consideration the beginning of a transition in which coexist the marine influence with a slight increase of vegetation. The progressive lagoon's depth loss favours the development of local vegetation on the shoreline. At the same time, the transgressive event took place, increasing the salinity, which could affect the vegetation, favouring a retraction of the scarce arboreal taxa, while well adapted to saline conditions herbs prevail. The presence of *Heleobia australis* occurs in elevated number from 300 cm to 180 cm, disappearing along the profile in subsequent phases.

### 5.1.3. Transitional coastal swamp (Phase II.c)

The progressive increase of arboreal taxa, and also the presence of *Cyatheaceae*, characteristic tree ferns of forest formations (Joly, 1966), seems to confirm the idea of a gradual increase in plant biomass. A peak of *Ludwigia*, which reaches a maximum frequency at the end of this period, reinforces the idea of a transitional environment influenced by water.

An illustrative feature of this sub-phase is the disappearance of palynoforaminifera linings, however, the presence of dinoflagellate cysts still indicates marine influence.

Between the middle/end of the previous sub-phase  $6245 \pm 50$  BP and the end of this,  $2797 \pm 48$  BP, 1 m of material was deposited in 3448 years, which implies a transformation of the existing palaeolagoon in a shallow marsh body subjected to groundwater level changes, the Araranguá River and its tributaries, and the oceanic influence (Fig. 4C).

This sub-phase is characterized as a succession stage in which the herbaceous and shrub formations gain prominence, allowing for a landscape arrangement composed by salinity adapted vegetation in the water bodies' shores, open salt marsh vegetation (*restinga*) associated to sandy stretches, alluvial vegetation following the Araranguá River and



an incipient Atlantic rain forest in process of migration from the Serra Geral slopes to West-East direction (Lorscheitter, 2003). Indeed, research in nearby areas show similar transitional conditions for these ages: brackish marsh ca. 2500 BP in Jaguaruna (Amaral et al., 2012), brackish swamp vegetation between 3800 and 2500 BP in the Sombrio (Cancelli, 2012) and an increase of freshwater algae parallel to the decline of marine palynomorphs in Tramandaí (Lorscheitter and Dillenburger, 1998).

Conceiving the Phase II as a whole, it is possible to understand its transitional character as a mosaic of different vegetal elements. According to the palynological study of surface sediments samples analysed in the lagoon and herbaceous/arboreal *restinga* of the Lagoa do Sombrio area (Cancelli, 2012), during this Phase II typical taxa of this *restinga* context nature (*Alchornea* and *Ilex*) appears combined with lagoonal elements (similar to Phase I) and arboreal taxa (mainly *Arecaceae* and *Myrtaceae*), that could be probably found as patches during Phase II before the forest expansion in the following Phase III. The fossil samples shared some fungal taxa which were also found in surface samples, such as *Nigrospora* type and other typical spores from transitional environments (Cancelli, 2012; Domsch et al., 1980).

#### 5.1.4. Forest expansion (Phase III)

In this phase, the typical Atlantic rain forest of lowlands taxa increased in concentration and diversity. It is remarkable the presence of epiphytic as *Cucurbitaceae*, indicating the advanced development of arboreal component in the forest (IBGE, 2012; Sevegnani and Schroeder, 2013). Some of the Atlantic rain forest arboreal taxa found in the fossil samples coincide with those identified in a pollen study from an undisturbed Atlantic rain forest in the North of the Santa Catarina State, which show that the most abundant pollen taxa are *Alchornea*, *Myrsine*, *Myrtaceae* and *Arecaceae* (Behling and Negrelle, 2006). Grass taxa percentages, less representative at this stage, also become more diverse, with cosmopolitan taxa that occur in swamps, marshes and bogs of the region (Irgang, 1974; Smith et al., 2004).

The absence of dinoflagellates cysts and palynoforaminifera linings provide evidences on the disappearance of marine influence, while the constant presence of freshwater algae indicates humid conditions.

The complete set of data, considering the sediment characteristics, that are entirely composed of organic mud, allows us to confirm the existence of a peat environment with very wet soils characterized by the constant rise of groundwater level related to rainfall variations.

Following the chronology of  $2205 \pm 05$  BP for the early stages of this phase, 2000 years were necessary for the 50 cm sedimentation of peat materials (Fig. 4D).

The disappearance of marine influence indicators suggests new edaphic conditions that allow vegetation expansion, therefore debris deposition and the progressive sedimentation phenomena, already in place, favoured the development of a forest and plant colonization. As a result, water bodies and marsh-lands in the area suffer a gradual decrease until their complete disappearance. In other cases, marshlands were reduced to smaller lagoons, as the currently existing: Serra lagoon, Bicho lagoon, Mãe Luzia-Esteves-Faxinal-Urussanga lagoonal complexes (Fig. 1C).

Favourable weather conditions, warm temperatures, and high humidity, also contributed to the Atlantic rain forest expansion, considered to have begun ca. 8000 BP from the slopes of the mountains to the East, progressively from South to North, reaching its highest point in the last two millennia in the northern Coastal Plain of Rio Grande do Sul, as in the southern Santa Catarina's Coastal Plain (Amaral et al., 2012; Bauermann, 2003; Cancelli, 2012; Lorscheitter and Dillenburger, 1998; Lorscheitter, 2003; Macedo et al., 2007; Meyer et al., 2005; Neves and Lorscheitter, 1995).

#### 5.1.5. Human occupation in a changing environment

The oldest phase and the two first sub-phases of Phase II (Phase I, Phases II.a and II.b), are characterized by an estuarine-lagoon

environment evolution, which suffers a progressive transformation into a coastal marsh.

Concerning the prehistoric occupation dynamics on the meridional Coastal Plain of the studied area, the absence of archaeological dated sites which could be included in this period demands further research-leading us to accept the present data- until new data leads to distinctive interpretations (Campos et al., 2013; Campos, 2015; Lavina, 2000; Lino, 2009).

When lowlands were flooded by water, the corresponding area with the existing palaeolagoon could not have been occupied contemporaneously by human groups (but their shores could have been). However, given the surface area available, if some settlements had existed before the moment of the maximum marine influence, these were eroded by water and buried below the lagoon sediment or deposited on its shores. This implies that the sites preserved on this surface are posterior to ca. 5100 BP, fact which coincides with current archaeological data.

Another hypothesis, is that sites in the Holocene barrier could have existed, as some researches in the municipalities of Jaguaruna, Tubarão and Laguna stated, with *sambaquis* with previous chronologies to the maximum eustatic (Giannini et al., 2010; Villagrán, 2012); however, current archaeological data in Araranguá municipality does not substantiate such evidence.

Following the course of the palaeoenvironmental evolution, during Phase II.c, in the deeper areas of the palaeolagoon, many smaller size water bodies (depressions) would have remained separated by new soils, not only suitable for the vegetation growth, but for the establishment of human groups. From this period of time it is possible to place the occupation of *sambaquis* builders', with a preference for the coastal line and/or lagoonal areas in their settlement patterns (Fig. 1C). An example is the excavated *sambaqui* Sambaqui do Geraldo/SC-IÇ-06 (Fig. 1C, archaeological site: A - Sambaqui do Geraldo/SC-IÇ-06), in Balneário Rincão municipality, with a chronology of  $3340 \pm 70$  BP (Rogge and Arnt, 2006).

In *sambaqui* SC-IÇ-06, faunal remains have been identified, especially marine molluscs (*Mesodesma* sp., *Donax* sp.), marine fish (*Archosargus* sp., *Centropomus* sp., *Micropogonias* sp.), brackish water fish (*Ariidae*), birds (*Diomedea* sp., *Spheniscus* sp. e *Puffinus* sp.), marine mammals (*Arctocephalus* sp.) and terrestrials mammals (*Tapirus* sp., *Ozotoceros bezoarticus*, *Tayassu* sp., *Mazama* sp.). The exploitation of aquatic food sources combined with terrestrial animal hunting implies that these environments could propitiate the acquisition of a wide range of resources, specially food, but also material for the elaboration of different objects, as seen in the presence of artefacts made of bone and shells, such as fish hooks, arrowheads and perforated shells (Rogge and Arnt, 2006).

SC-IÇ-06 site displays a pattern of later settlement when compared with the North-Central area of Santa Catarina (Giannini et al., 2010) where some marine animals acts as seasonal indicators, which combined with the reduced size of the shellmound could suggest a seasonal occupation of the site. However, this site is located between Torres and Tramandaí municipalities in the Rio Grande do Sul state, and Laguna and Jaguaruna municipalities in Santa Catarina state, which are two important points of *sambaqui* culture expansion (DeBlasis et al., 2007; Gaspar et al., 2008; Wagner, 2009). That is why the absence of shellmounds in the studied area during the period of greater expansion of *sambaquis* builders' groups (5000–3000 BP) is probably because of sampling bias due to the lack of systematic and extensive archaeological survey in the region, than to different settlement patterns.

Anthracological research in *sambaquis* of meridional regions of Southern Brazil, confirms a settlement preference of these groups for coastal lands near coastal forest and mangroves (Scheel-Ybert, 2013). Transitional environments, like mangroves or brackish swamps, have a great ecological importance serving as protection to diverse organisms and, consequently, being an important source of resources for human groups (Sevegnani and Schroeder, 2013). Anthracological research also

reveals the presence of charred plant remains in different *sambaquis* of Southern Brazil, being the most common the *Syagrus* sp. and *Butia* sp. endocarps, and seeds belonging to *Myrtaceae*, *Annonaceae*, *Cucurbitaceae* and *Cyperaceae* families (Scheel-Ybert, 1999, 2013; Scheel-Ybert et al., 2003); all of them appear in the analysed samples establishing a correspondence to this period.

It is possible to situate hunter-gatherer settlements in the mountain slopes. The nearest excavated sites with chronological dating (in Alfredo Wagner, Urubici and Presidente Getúlio municipalities) show an occupation from  $3000 \pm 120$  to  $660 \pm 80$ – $290 \pm 80$  BP. Considering the identification of hunter-gatherer sites in inland areas of the Araranguá municipality Coastal Plain (Campos et al., 2013; Campos, 2015), one may admit sporadic incursions on the coast for resources' exploitation, which could have resulted in seasonal settlements of such groups (Fig. 1C, archaeological sites: X - Oraldo Bristote and Z - Morro Espigão da Pedra).

During the last 2500 years BP (Phase III), the region gained similar characteristics to those of present times, with a salt marsh vegetation (*restinga*) in the sandy areas of the beach and shoreline, forests composed of a large biodiversity in soils less affected by salinity, and a variety of ecosystems related to freshwater sources, brackish water bodies and the sea.

In general terms, shell midden builders' occupation observed continuity until ca. 2000–1500 BP, when it is considered that elements assigned to Meridional Jê starting to be incorporated (Milheira and DeBlasis, 2013). The excavated Meridional Jê, Jazigo Mortuário/SC-IC-01 (Fig. 1C, archaeological site: D - Jazigo Mortuário/SC-IC-01), is located in the Içara municipality and has a chronology of  $1580 \pm 50$  BP (Schmitz, 1995, 1999). The interpretation of this particular site is problematic and the data does not allow an exhaustive analysis on resource exploitation of this group in the littoral areas. However, new data on a Meridional Jê site in Bonin (1300–1439 BP and 1297–1414 BP, Urubici municipality) has revealed, through the study of starch grains and phytoliths, the consumption of vegetal resources (some of them gathered and others cultivated) such as beans (*Phaseolus* sp.), manioc (*Manihot esculenta*), possibly yams (cf. *Dioscorea* sp.), maize (*Zea mays*) and squash (*Cucurbita* sp.) (Corteletti et al., 2015). Avoiding direct comparisons, this lead us to question if these groups would practice a similar vegetal resource management in the littoral (where it is possible to gather and cultivate the same species), what kind of settlement patterns could be related with these practices, etc. The continuity of Meridional Jê occupations seems to extend throughout this period until the arrival of the Guarani groups ca. 700 BP (Noelli, 1999, 2000).

Coinciding with the Atlantic rain forest consolidation (Phase III), the best represented group is formed by the Guaranis. The excavated sites in Araranguá and Balneário Rincão municipalities situate the Guarani's occupation over the last 700 years BP until the arrival of Europeans (Campos et al., 2013; Campos, 2015; Lavina, 2000; Lino, 2009).

In the municipality of Araranguá, the spatial distribution of settlements suggests a pattern of proximity in relation to the Araranguá River, mostly, but also to its tributary Porcos' River (Fig. 1C), which channel would be clearly defined at this stage (Fig. 4D). At the same time, the vast majority of these sites are located in the area of the lagoonal belt (Fig. 1C, archaeological sites: B - Aldeia do Cemitério da Lagoa dos Esteves, C - Aldeia da Lagoa Mãe Luzia, E - Aldeia Roça de Melancia, H - Campo Mãe Luzia IV, I - Campo Mãe Luzia III, J - Campo Mãe Luzia II, K - Campo Mãe Luzia I, L - Aldeia Roça de Milho, S - SC-ARA-049, U - SC-ARA-051, and V - Aldeia da Balsa), usually in the sandy and elevated terrains of palaeodunes (Campos, 2015); this surface includes alluvial, *restinga* and forest vegetation types, with a diverse fauna associated to each one of them.

In the Campo Mãe Luzia sites (Fig. 1C, archaeological sites: H - Campo Mãe Luzia IV, I - Campo Mãe Luzia III, J - Campo Mãe Luzia II, and K - Campo Mãe Luzia I), faunal remains were mostly mollusks, almost all terrestrial gastropods of *Megalobulimus* genus and, in a lesser

degree, marine as *Olivancillaria vesica*. Some charred seeds were recovered, all belonging to the genus *Butia* (Campos, 2015).

Guarani groups were considered as horticulturists, and the sandy areas, where their settlements were located, favoured the production of mandioca -*Euphorbiaceae*-, squash -*Cucurbitaceae*- and corn -*Poaceae*- (Milheira, 2010, 2014). Pollen of these three families were identified in the samples corresponding to this period. However, it was not possible to confirm the presence of cultivated fields over the last 700 years for several reasons: it was not possible to reach the species level in the identifications; *Euphorbiaceae* family is only represented by *Acalypha*, *Alchornea* and *Sebastiania*; *Poaceae* family was identified along all the sequence; and the only one of these families with high frequencies in this phase is *Cucurbitaceae*, which does not deny the possibility of cultivable species, however, does not appear within a coherent context to argue a clear presence of agriculture. However, it is important to conceive the forest expansion as an increase of resources that could be exploited, regardless of the existence of agricultural practices.

## 6. Conclusions

The first insights in the palynological study of a natural deposit in Campo Mãe Luzia reveal the palaeoenvironmental evolution in the southern Coastal Plain of Santa Catarina for the last 8000 years BP. The palynological, sedimentary, chronological and altimetric records indicate the existence of three phases with different environmental and ecological characteristics associated with climate variations, sea level fluctuations, and regional dynamics, hence the development of the Holocene barrier and the presence of the Araranguá River.

The integration of archaeological data with palynological data, supported by anthracological and faunal data, allowing for the contextualization of the different groups within each environmental phase. The hunter-gatherer groups and the Meridional Jê present greater characterization difficulties when compared to *sambaquis* builders' and Guarani groups, the latter are better known due to the advanced level of research. The following dynamics were observed:

The hunter-gatherer sites appear in low number in the Coastal Plain areas that are closer to the slopes of the Serra Geral. Considering that highlands were the group's preferred settlement location, though it could indicate sporadic incursions to the littoral. Chronologies of the nearest excavated sites ( $3000 \pm 120$  BP,  $910 \pm 200$  BP and  $290 \pm 80$  BP) situate them from the Phase II.b onwards.

Meridional Jê sites are better known in the highlands than in the littoral, where they appear associated with surface layers of *sambaquis*, making it difficult to interpret their settlement patterns. Regional data situate them in Phase III, more specifically from around 1500 to 700 years BP. The data obtained in the Bonin site revealed some patterns of vegetal consumption in the highlands related with gathering and cultivation practices. Although we should not extrapolate archaeological data from a site located in the highlands with those located in the littoral plain, it is interesting to acknowledge the adaptive strategies of this group in this specific ecosystem (settlement patterns, exploitation of resources, etc.) in order to study their archaeological littoral sites from a new point of view.

*Sambaquis* builders' groups show a settlement pattern related to coastal environments, especially lagoon environments, which allowed them to display resources exploitation of all the existing ecosystems within a proximity radius. At a regional level, the chronology of SC-IC-06 situates them in the Phase II.b and Phase III. The controversial "archaeological gap" related to the absence of older *sambaquis* settlements in this region could be probably due to the need of systematic and extensive archaeological surveying.

Guarani settlements are mostly located in the area of the lagoonal belt, near the Araranguá River and its tributary Porcos' River. Guarani groups also exhibit settlements in large rivers of highland valleys, which imply an exploration of diverse and geographically distant environments, with rivers being the common elements. Coastal



Archaeological data contributed to a better understanding of human settlements during the last 700 years BP, after the consolidation of the Atlantic rain forest (Phase III), displaying resource exploitation practices of aquatic and terrestrial animals, as well as forest plant resources.

## Acknowledgements

This research is linked to the research project “Arqueologia Entre Rios do Urussanga ao Mampituba”, it was developed by the Research Group in Archeology and Integrated Management of Territory of the Universidade do Extremo Sul Catarinense (UNESC). It was supported by the Universidade do Extremo Sul Catarinense (UNESC) through the projects 01510.001172/2011-74 (IPHAN) and 455865/2014-2 (CNPq), and by the Instituto de Geociências of the Universidade Federal de Rio Grande do Sul (UFRGS), through the project 454804/2014-8 (CNPq). We thank to the Laboratório de Palinologia Marleni Marques Toigo (UFRGS) and to the Laboratório de Interação Animal-Planta (UNESC) for their collaboration in different steps of the research. This paper profited from helpful comments by Paulo DeBlasis and Jedson Cerezer.

## References

- Amaral, P.G.C., Giannini, P.C.F., Sylvestre, F., Pessenda, L.C.R., 2012. Paleoenvironmental reconstruction of a Late Quaternary lagoon system in southern Brazil (Jaguaruna region, Santa Catarina state) based on multi-proxy analysis. *J. Quat. Sci.* 27 (2), 181–191. <http://dx.doi.org/10.1002/jqs.1531>.
- Barboza, E.G., Rosa, M.L.C.C., Dillenburg, S.R., Silva, A.B., Tomazelli, L.J., 2014. Stratigraphic analysis applied on the recognition of the interface between marine and fluvial depositional systems. *J. Coast. Res.* 70, 687–692. <http://dx.doi.org/10.2112/S170-116.1>.
- Baumann, S.G., 2003. Análises palinológicas e evolução paleovegetacional e paleoambiental das turfeiras de Barrocas e Águas Claras, Planície Costeira do Rio Grande do Sul, Brasil (PhD Thesis). Universidade Federal de Rio Grande do Sul, Brazil. <http://dx.doi.org/10.13140/RG.2.2.33026.68800>.
- Behling, H., 1995. A high resolution Holocene pollen record from Lago do Pires, SE Brazil: vegetation, climate and fire history. *J. Paleolimnol.* 14, 235–268. <http://dx.doi.org/10.1007/BF00682427>.
- Behling, H., Negrelle, R.R.B., 2001. Tropical rain forest and climate dynamics of the Atlantic Lowland, Southern Brazil, during the Late Quaternary. *Quat. Res.* 56 (3), 383–389. <http://dx.doi.org/10.1006/qres.2001.2264>.
- Behling, H., Negrelle, R.R.B., 2006. Vegetation and pollen rain relationship from the tropical Atlantic rain forest in Southern Brazil. *Braz. Arch. Biol. Technol.* 49 (4), 631–642. <http://dx.doi.org/10.1590/S1516-89132006000500013>.
- Campos, J.B., 2015. Arqueologia Entre Rios e Gestão Integrada do Território no Extremo Sul de Santa Catarina-Brasil (PhD Thesis). Universidade de Trás-os-Montes e Alto Douro, Portugal.
- Campos, J.B., Santos, M.C.P., Rosa, R.C., Ricken, C., Zocche, J.J., 2013. Arqueologia Entre Rios: do Urussanga ao Mampituba. Registros arqueológicos pré-históricos no extremo sul catarinense. *Cadernos do LEPAARQ* 10 (20), 9–40.
- Cancelli, R.R., 2012. Evolução paleoambiental da Planície Costeira Sul-Catarinense (Lagoa do Sombrio) durante o Holoceno, com base em dados palinológicos (PhD Thesis). Universidade Federal de Rio Grande do Sul, Brazil.
- Cancelli, R.R., Souza, P.A., Neves, P.C.P., 2012a. Fungos, criptógamas e outros palinó-morfos holocênicos (7908 ± 30 anos AP-atual) da Planície Costeira sul-catarinense, Brasil. *Acta Bot. Bras.* 26 (1), 27–44. <http://dx.doi.org/10.1590/S0102-33062012000100004>.
- Cancelli, R.R., Souza, P.A., Neves, P.C.P., 2012b. Grãos de pólen de angiospermas do Holoceno (7908 ± 30 anos AP-atual) da Planície Costeira sul-catarinense, Brasil. *Acta Bot. Bras.* 26 (4), 866–885. <http://dx.doi.org/10.1590/S0102-33062012000400016>.
- Colinvaux, P.A., De Oliveira, P.E., Patiño, J.E., 1999. Amazon Pollen Manual and Atlas. *Hardwood Academic Publishers*, Amsterdam.
- Cordazzo, C.V., Seeliger, U., 1995. Guia ilustrado da vegetação costeira no extremo sul do Brasil. *FURG, Rio Grande do Sul*.
- Corteletti, R., Dickau, R., DeBlasis, P., Iriarte, J., 2015. Revisiting the economy and mobility of southern proto-Jê (Taquara-Itararé) groups in the southern Brazilian highlands: starch grain and phytolith analyses from the Bonin site, Urubici, Brazil. *J. Archaeol. Sci.* 58, 46–61. <http://dx.doi.org/10.1016/j.jas.2015.03.017>.
- DeBlasis, P., Kneip, A., Scheel-Ybert, R., Giannini, P.C.F., Gaspar, M.D., 2007. Sambaquis e Paisagem: Dinâmica Natural e Arqueologia Regional no Litoral Sul do Brasil. *Revista de Arqueologia Sudamericana* 3 (1), 29–61.
- Dias, A.S., 2004. Diversificar para poblar: El contexto arqueológico brasileño en la transición Pleistoceno-Holoceno. *Complutum* 15, 249–263. <http://dx.doi.org/10.5209/CMPL30774>.
- Diehl, F.L., Horn Filho, N.O., 1996. Compartimentação geológica-geomorfológica da zona litorânea e planície costeira do Estado de Santa Catarina. *Notas Técnicas* 9, 90–93.
- Dillenburg, S.R., Barboza, E.G., 2014. The strike-fed sandy coast of Southern Brazil. In: Martini, I.P., Wanless, H.R. (Eds.), *Sedimentary Coastal Zones from High to Low Latitudes: Similarities and Differences*. Special Publications, London, pp. 333–352. <http://dx.doi.org/10.1144/SP388.16>.
- Dillenburg, S.R., Barboza, E.G., Tomazelli, L.J., Hesp, P.A., Clerot, L.C.P., Zouain, R.N.A., 2009. The Holocene Coastal Barriers of Rio Grande do Sul. In: Dillenburg, S.R., Hesp, P.A. (Eds.), *Geology and Geomorphology of Holocene Coastal Barriers of Brazil*. Springer, Heidelberg, pp. 53–91. [http://dx.doi.org/10.1007/978-3-540-44771-9\\_3](http://dx.doi.org/10.1007/978-3-540-44771-9_3).
- Domsch, K.H., Gams, W., Anderson, T.H., 1980. *Compendium of Soil Fungi*. Academic Press, London. <http://dx.doi.org/10.1111/j.1365-2389.2008.01052.1.x>.
- Faegri, K., Iversen, J., 1989. *Textbook of Pollen Analysis*. Hafner, New York. <http://dx.doi.org/10.1002/jqs.3390050310>.
- Farias, D.S., 2005. Distribuição e padrão de assentamento-propostas para os sítios da Tradição Umbu na encosta de Santa Catarina (PhD Thesis). Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.
- Gaspar, M.D., DeBlasis, P., Fish, S.K., Fish, P.R., 2008. Sambaqui (shell mound) societies of Coastal Brazil. In: Silverman, H., Isbell, W. (Eds.), *Handbook of South American Archaeology*. Springer, New York, pp. 319–335. [http://dx.doi.org/10.1007/978-0-387-74907-5\\_18](http://dx.doi.org/10.1007/978-0-387-74907-5_18).
- Giannini, P.C.F., Sawakuchi, A.O., Martinho, C.T., Tatum, S.H., 2007. Eolian depositional episodes controlled by Late Quaternary relative sea level changes on the Imbituba-Laguna coast (southern Brazil). *Mar. Geol.* 237, 143–168. <http://dx.doi.org/10.1016/j.margeo.2006.10.027>.
- Giannini, P.C.F., Villagrán, X.S., Fornari, M., Rodrigues, D., Menezes, P., Tanaka, A.P., Assunção, D., De Blasis, P., Amaral, P., 2010. Interações Entre Evolução Sedimentar e Ocupação Humana Pré-histórica Na Costa Centro-sul De Santa Catarina, Brasil. *Boletim do Museu Paraense Emílio Goeldi Série Ciências Humanas* 5 (1), 105–128. <http://dx.doi.org/10.1590/S1981-81222010000100008>.
- Grimm, E.C., 1987. CONISS: a FORTRAN 77 program for stratigraphically constrained cluster analysis by method of the incremental sum of squares. *Comput. Geosci.* 13, 13–35. [http://dx.doi.org/10.1016/0098-3004\(87\)90022-7](http://dx.doi.org/10.1016/0098-3004(87)90022-7).
- Hesp, P.A., Giannini, P.C.F., Martinho, C.T., Silva, G.M., Asp, N.E., 2009. The Holocene barrier systems of the Santa Catarina Coast, Southern Brazil. In: Dillenburg, S.R., Hesp, P.A. (Eds.), *Geology and Geomorphology of Holocene Coastal Barriers of Brazil*. Springer, Heidelberg, pp. 93–133. [http://dx.doi.org/10.1007/978-3-540-44771-9\\_4](http://dx.doi.org/10.1007/978-3-540-44771-9_4).
- Hogg, A.G., Hua, Q., Blackwell, P.G., Niu, M., Buck, C.E., Guilderson, T.P., Heaton, T.J., Palmer, J.G., Reimer, P.J., Reimer, R.W., Turney, C.S.M., Zimmerman, S.R.H., 2013. SHCal13 southern hemisphere calibration, 0–50,000 years cal BP. *Radiocarbon* 55 (4), 1889–1903. [http://dx.doi.org/10.2458/azu\\_js\\_rc.55.16783](http://dx.doi.org/10.2458/azu_js_rc.55.16783).
- Horn Filho, N.O., Polzin, M.A., Machado, C., Machado, V.C., Leal, R.A., Malandrini, D.A., Silva, A.F., Oliveira, D.A.G., Floriani, D.C., Westar, E., de F.F. do, A., Damasio, M., Freitas, M.P., Farion, S.R.L., de Oliveira, U.R., Diebe, V.C., Peixoto, J.R.V., Silva, M., 2012. Mapa geológico da planície costeira das folhas Rincão (SH-22-X-B-IV-4), Araranguá (SH-22-X-B-IV-3) e Turvo (SH-22-X-A-VI-4), Santa Catarina, Brasil. In: Horn Filho, N.O. (Ed.), *Atlas geológico da planície costeira do estado de Santa Catarina em base ao estudo dos depósitos quaternários. Série mapas IBGE—Mapa n°10. Escala 1:100.000 UFSC/CFH-CNPq, Florianópolis*.
- Instituto Brasileiro de Geografia e Estatística (IBGE), 2012. *Manual Técnico da Vegetação Brasileira*. IBGE, Rio de Janeiro.
- Irgang, B.E., 1974. Flora Ilustrada do Rio Grande do Sul. *Umbelliferae II, Gênero Eryngium L.* 32. *Boletim do Instituto Central de Biociências Série Botânica*, pp. 1–86.
- Joly, A.B., 1966. *Botânica: introdução à taxonomia vegetal*. Ed.Nacional, São Paulo.
- Köppen, W., 1948. *Climatologia: con un estudio de los climas de la Tierra*. Fondo de Cultura Económica, México.
- Lavina, R., 2000. Relatório Final do Projeto de Salvamento Arqueológico da Rodovia Interpauas (Trecho Morro dos Conventos-Lagoa dos Esteves). UNESC, Criciúma.
- Leal, M.G., Lorscheitter, M.L., 2006. Pólen, esporos e demais palinó-morfos de sedimentos holocênicos de uma floresta paludosa, Encosta Inferior do Nordeste, Rio Grande do Sul, Brasil. *Iheringia Série Botânica* 61 (1–2), 13–47.
- Leonhardt, A., Lorscheitter, M.L., 2007. Palinó-morfos do perfil sedimentar de uma turfeira em São Francisco de Paula, Planalto Leste do Rio Grande do Sul, Sul do Brasil. *Rev. Bras. Bot.* 30 (1), 47–59.
- Lino, J.T., 2009. Arqueologia guarani na bacia hidrográfica do Rio Araranguá, Santa Catarina (PhD Thesis). Universidade Federal de Rio Grande do Sul, Brazil.
- Lorscheitter, M.L., 1988. Palinologia de sedimentos quaternários do testemunho T15, Cone do Rio Grande, Atlântico Sul, Brasil. In: *Descrições taxonômicas. 21. Pesquisas*, pp. 61–117.
- Lorscheitter, M.L., 1989. Palinologia de sedimentos quaternários do testemunho T15, Cone do Rio Grande, Atlântico Sul, Brasil. In: *Descrições taxonômicas - parte II. 22. Pesquisas*, pp. 89–127.
- Lorscheitter, M.L., 2003. Contribution to the Holocene history of Atlantic rain forest in the Rio Grande do Sul state, southern Brazil. *Revista del Museo Argentino de Ciencias Naturales* 5 (2), 261–271.
- Lorscheitter, M.L., Dillenburg, S.R., 1998. Holocene Paleoenvironments of the Northern Coastal Plain of Rio Grande do Sul, Brazil, reconstructed from palynology of Tramandaí Lagoon sediments. *Quaternary of South America and Antarctic Peninsula* 11 (1), 73–97.
- Lorscheitter, M.L., Roth, L., 2013. O Uso da Concentração Polínica em Interpretações Paleoambientais. *Anuário do Instituto de Geociências-UFRJ* 36 (1), 80–84. [http://dx.doi.org/10.11137/2013\\_1\\_80\\_84](http://dx.doi.org/10.11137/2013_1_80_84).
- Macedo, R.B., Cancelli, R.R., Baumann, S.G., de Bordignon, S.A.L., Neves, P.C.P., 2007. Palinologia de níveis do Holoceno da Planície Costeira do Rio Grande do Sul (localidade de Passinhos), Brasil. *Gaea* 7, 68–74.
- Macedo, R.B., Souza, P.A., Baumann, S.G., 2009. Catálogo de pólenes, esporos e demais palinó-morfos em sedimentos holocênicos de Santo Antonio da Patrulha, Rio Grande do Sul, Brasil. *Iheringia Série Botânica* 62 (2), 43–78.
- Medeian, S., 2006. Freshwater algal palynomorph records from the Holocene deposits in the coastal plain of Rio Grande do Sul. *Rev. Paleobot. Palynol.* 141 (1–2), 83–101. <http://dx.doi.org/10.1016/j.revpalbo.2006.03.012>.

- Medeanic, S., Córrea, I.C.S., 2010. Climatic changes in the coastal plain of the Rio Grande do Sul satate in the Holocene: palynomorph evidences. *Pan-American Journal of Aquatic Sciences* 5 (2), 287–297.
- Medeanic, S., Córrea, I.C.S., Weschenfelder, J., 2007. Palinomorfos nos Sedimentos de Fundo da Laguna dos Patos-RS: Aplicação nas Reconstruções Paleoambientais. *Gravel* 5, 89–102.
- Medeanic, S., Hirata, F., Dillenburg, S.R., 2010. Algal Palynomorphs response to environmental changes in the Tramandai Lagoon, Southern Brazil, and climatic oscillations in the 20th century. *J. Coast. Res.* 26, 726–735. <http://dx.doi.org/10.2112/08-1175.1>.
- Meyer, K.E.B., Mendonça Filho, J.G., Ashraf, A.R., Souza, P.A., Reichhart, K., 2005. Análise de palinofácies em sedimentos holocênicos da Lagoa dos Quadros, Planície Costeira do Rio Grande do Sul, Brasil. *Revista Brasileira de Paleontologia* 8 (1), 57–72.
- Milheira, R.G., 2010. Arqueologia Guarani no litoral sul-catarinense: História e Território (PhD Thesis). Universidade de São Paulo, São Paulo; Brasil.
- Milheira, R.G., DeBlasis, P., 2013. Ocupação do território guarani no litoral sul-catarinense. *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano-Series especiales* 1 (4), 148–160.
- Milheira, R.G., 2014. Arqueologia Guarani na ponta sul do Brasil. Editora da Universidade Federal de Pelotas, Pelotas.
- Neves, P.C.P., Lorscheitter, M.L., 1992. Palinologia de sedimentos de uma mata tropical paludosa em Terra de Areia, Planície Costeira Norte, Rio Grande do Sul, Brasil. *Descrições taxonômicas, parte I: fungos, algas, briófitos, pteridófitos, palinomorfos outros e fragmentos de invertebrados. Acta Geol. Leopold.* 15, 83–114.
- Neves, P.C.P., Lorscheitter, M.L., 1995. Palinologia de sedimentos de uma mata tropical paludosa (Terra de Areia, Planície Costeira Norte, Rio Grande do Sul, Brasil). *Descrições Taxonômicas—Parte II: Gimnospermas e Angiospermas. Acta Geol. Leopold.* 41, 45–82.
- Nimer, E., 1989. Climatologia do Brasil. IBGE, Rio de Janeiro.
- Noelli, F.S., 1999. Repensando os rótulos e a história dos Jê no sul do Brasil a partir de uma interpretação interdisciplinar. *Revista do Museu de Arqueologia e Etnologia* 3, 285–302.
- Noelli, F.S., 2000. A ocupação humana na Região Sul do Brasil: arqueologia, debates e perspectivas 1827–2000. *Revista USP* 44, 218–269. <http://dx.doi.org/10.11606/issn.2316-9036.v0i44p218-269>.
- Prous, A., 1991. Arqueologia Brasileira. Universidade de Brasília, Brasília.
- Reitz, R., 1961. Vegetação da zona marítima de Santa Catarina. *Sellowia* 13 (163), 17–115.
- Rogge, J.H., Arnt, F.V., 2006. O Sambaqui de Içara SC-IC-06. In: *Pesquisas Antropologia*. 63. pp. 13–16.
- Scheel-Ybert, R., 1999. Paleoambiente e paleoetnologia de populações sambaquieiras do sudeste do Estado do Rio de Janeiro. In: *Revista do Museu de Arqueologia e Etnologia de São Paulo*. 9. pp. 43–59.
- Scheel-Ybert, R., 2013. Preliminary data on nonwood plant remains at sambaquis from the Southern and Southeastern Brazilian coast: considerations on diet, ritual and site particularities. *Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano-Series especiales* 1 (1), 60–72.
- Scheel-Ybert, R., Eggers, S., Wesolowski, V., Petronilho, C.C., Boyadjian, C.H., DeBlasis, P., Barbosa-Guimaraes, M., Gaspar, M.D., 2003. Novas perspectivas na reconstituição do modo de vida dos sambaquieiros: uma abordagem multidisciplinar. In: *Revista de Arqueologia SAB*. 16. pp. 109–137.
- Schmitz, P.I., 1995. Acampamentos Litorâneos em Içara-SC. *Um Exercício em Padrão de Assentamento. Cliometrica* 1 (11), 99–118.
- Schmitz, P.I., 1999. Içara: um Jazigo Mortuário no litoral de Santa Catarina. In: *Antropologia*. 55. Pesquisas, pp. 1–164.
- Schmitz, P.I., 2013. A ocupação Pré-Histórica do Estado de Santa Catarina. *Tempos Acadêmicos* 11, 6–24.
- Sevegnani, L., Schroeder, E., 2013. Biodiversidade catarinense: características, potencialidades, ameaças. Edifurb, Blumenau.
- Silva, A.B., 2015. A Herança geológica, a geomorfologia e a estratigrafia da Barreira complexa de Passo de Torres, Planície Costeira Sul-catarinense (PhD Thesis). Universidade Federal de Rio Grande do Sul, Brazil.
- Silva, B.A., Barboza, E.G., Rosa, M.L.C.C., Fracalossi, F.G., 2010. Caracterização dos Depósitos Sedimentares em Subsuperfície no Setor Meridional da Planície Costeira Sul de Santa Catarina. *Gravel* 8 (1), 1–7.
- Silva, B.A., Barboza, E.G., Rosa, M.L.C.C., Dillenburg, S.R., 2014. Meandering fluvial system influencing the evolution of a Holocene regressive barrier in southern Brazil. *J. Coast. Res.* 70, 205–210. <http://dx.doi.org/10.2112/SI70-035.1>.
- Smith, N., Mori, S., Henderson, A., Stevenson, D.W., Heald, S.V., 2004. Flowering Plants of Neotropics. Princeton University Press, Princeton. [http://dx.doi.org/10.1658/1100-9233\(2004\)015\[0853:BRJ2.0.CO;2](http://dx.doi.org/10.1658/1100-9233(2004)015[0853:BRJ2.0.CO;2).
- Stockmarr, J., 1971. Tablets with spores used in absolute pollen analysis. *Pollen Spores* 13, 615–621.
- Talma, A.S., Vogel, J.C., 1993. A simplified approach to calibrating C14 dates. *Radiocarbon* 35 (2), 317–322.
- Villagrán, X.S., 2012. Micromorfologia de sítios concheiros da América do Sul: arqueostratigrafia e processos de formação de sambaquis (Santa Catarina, Brasil) e concheiros (Terra do Fogo, Argentina) (PhD Thesis). Universidade de São Paulo, Brazil.
- Villwock, J.A., Tomazelli, L.J., 1995. Geologia Costeira do Rio Grande do Sul. *Notas Técnicas* 8, 1–45.
- Villwock, J.A., Tomazelli, L.J., Loss, E.L., Dehnhardt, E.A., Horn Filho, N.O., Bachi, F.A., Dehnhardt, B.A., 1986. Geology of the Rio Grande do Sul Coastal Province. In: *Rebassa, J. (Ed.), Quaternary of South America and Antarctic Peninsula*. Vol. 4. Balkema, Rotterdam, pp. 79–97.
- Wagner, G.P., 2009. Sambaquis da Barreira da Itapeva: uma perspectiva geoarqueológica (PhD Thesis). Pontifícia Universidade Católica do Rio Grande do Sul, Brazil.